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Subject: WTC 7 Draft Report Comments

Comments on the Draft Report NIST NCSTAR 1-9: “*Structural Fire Response and Probable Collapse Sequence of World Trade Center Building 7*”, issued by NIST August 21st, 2008

By

F. R. Greening

1.0 Introduction

A preliminary (draft) version of NIST’s final report on the collapse of WTC 7 was issued on August 21st 2008 together with a call by NIST’s Investigation Team for the submission of comments on the Draft Report from interested parties within the general public. First I wish to thank NIST for producing such a detailed technical report on the collapse of WTC 7 and secondly, I applaud NIST for allowing researchers from around the world to offer technical feedback that hopefully will be duly considered by NIST before a final version of the report is issued.

In reading the Draft WTC 7 Report a number of issues emerge that are crucial to the credibility of NIST’s proposal as to how and why building 7 collapsed on September 11th, 2001. These key issues center on the narrative surrounding the ignition of the fires in WTC 7 and the spreading of these fires within the building prior to its collapse. The accuracy of NIST’s account of what transpired within the confines of building 7 during 9/11, is vital to NIST’s entire WTC 7 Report because it provides the basis for the computer modeling/simulation of the heating of structural elements on the fire-affected floors, which in turn, leads to NIST’s proposed collapse initiation and propagation mechanism.

In the following comments I will attempt to address each of the key topics - fire ignition and spreading, fire intensities and durations, structural heating, collapse initiation and propagation – and in so doing, highlight my concerns or objections to NIST’s position on these topics as presented in its Draft WTC 7 Report.

2.0 The Ignition and Spreading of the Fires in WTC 7

In Chapter 9 of NIST NCSTAR 1-9 we encounter one of the most significant problems with attempts to unravel the mystery of why and how WTC 7 collapsed late in the afternoon of September 11th, 2001 – the question of where and how fires started in building 7. On page 376 of NCSTAR 1-9 we read:

“... the ignition and early course of the fires (in WTC 7) were unknown because they were presumed to have occurred in the damaged and heavily smoke-shrouded southern portion of the building.”

NIST's knowledge of the fires in WTC 7 is therefore based on images of the *exterior faces* of the buildings. Unfortunately however, as acknowledged by NIST, most of the burning of combustible materials at the WTC on 9/11 took place beyond the views available through exterior windows well *inside* the buildings.

NIST propose, and it appears to be a reasonable assumption, that the fires in WTC 7 started near the south face as a result of the collapse of WTC 1 at about 10:29 on the morning of 9/11.

However, even this assumption is problematical because fires on the crucial 12th and 13th floors of WTC 7 were not in fact observed until after 2:00 p.m., and then only on the *east* face of the building.

Faced with the problem of modeling the spreading of the fires in WTC 7, NIST begins its computer simulation with a set of 2 MW fires, presumably one per floor, for floors 7, 8, 9, 11, 12 and 13. These hypothetical fires are stated to be "*roughly equivalent to small, single workstation fires*", but NIST is quite vague about *where* these fires were located other than "*near the southern face of the building*". What is more, for the fire to spread to NIST's satisfaction on floor 8, *two* fires were hypothesized to start at this level within the building.

Other aspects of NIST's simulation also appear to be quite arbitrary and unphysical. Thus the fire on floor 12 was prescribed to start "*near the center of the south face at an assigned time of 12:00 noon*." This is a strange choice of ignition time given that the WTC 7 fires were supposedly started by flaming debris from the collapse of WTC 1 at 10:29 a.m. It implies that some of the flaming material in the WTC 1 debris that settled near WTC 7 remained dormant for about an hour and a half before spontaneously igniting fires that were subsequently observed on floor 12.

1.0 Fire Intensities and Durations

The way the fires spread in WTC 7 during 9/11 was largely determined by the distribution of combustible materials throughout the building. In NIST's fire simulations this distribution was approximated by an average fuel load for each fire-affected floor of 20 - 32 kg/m² or 4.0 and 6.4 lb/ft², (See NIST NCSTAR 1-9 pages 59 - 60). As shown in Figures 10-15 and 10-16 of NCSTAR 1-9, this fuel loading is calculated by NIST to have been sufficient to sustain temperatures above 400 °C for the floor beams and concrete slab on the east side of floors 12 and 13 for about 2 hours. According to NIST's fire simulations, floors 12 and 13 were the most severely heated floors in WTC 7; however, there are reasons to question the level of heating claimed by NIST.

NIST's fire simulation would have us believe that a very substantial heat release rate was sustained for over 2 hours over a floor area of about 500 m² in building 7. Thus Figure 9-13 of NCSTAR 1-9 shows that a heat release rate of 200 MW was attained on floor 12 at about 3:00 p.m. on September 11th and remained above 200 MW until well after 5:00 p.m. But we need to ask: Is a 200 MW fire consistent with a fuel loading of 32 kg/m² - the value used by NIST for its floor 12 fire simulations? The answer appears to be no. Thus a 200 MW heat release rate for 2 hours implies a total energy release of 1,440 GJ. If the combustible material on the 12th floor of WTC 7 is assumed to release 20 MJ/kg, we have to conclude that 72,000 kg of office material was combusted over an area of 500 m², or there was a fuel loading in WTC 7 of 144 kg/m² - a value over four times NIST's assumed fuel loading.

That there is a problem with NIST's predicted fire intensities in WTC 7 compared to the assumed fuel loading is supported by comparisons to other studies of fires in steel framed buildings. For example, the well-known Cardington tests conducted in the U.K. in 1999 measured a maximum heat flux of about 200 kW/m^2 over a period of about 1 hour from the combustion of 6000 kg of cellulose-based fuel inside a 144 m^2 steel framed structure, giving a fuel loading of 42 kg/m^2 . Thus we see that in the Cardington tests the total energy release is predicted to be $144 \times 200 \text{ kW}$ for one hour which equals 28.8 MW for 3600 seconds or 104 GJ. The heat of combustion of the fuel was 17 MJ/kg, so for 6000 kg we would expect a heat release of 102 GJ in good agreement with the predicted energy release.

The main problem with the NIST fire simulation appears to be the calculated *duration* of the fire on the 12th and 13th floors of WTC 7. For example, if we assume a more reasonable fire duration of 30 minutes, rather than NIST's excessive 2 hours, we may revise the energy release down from 1,440 GJ to a mere 360 GJ in which case the combustion of 20 MJ/kg fuel would have consumed 18,000 kg of material and the fuel loading would have been 36 kg/m^2 in much better agreement with NIST's assumed fuel load. That these are more realistic figures is also supported by some of NIST's own studies of the relationship between combustible loads in buildings and classifications of fire severity. Thus M G. Goode in NIST Report No. GCR-04-872, published in July 2004, provided a table showing that fire durations of 0.5 and 0.75 hours are to be expected for fuel loads of 20 kg/m^2 and 30 kg/m^2 , respectively.

4.0 Structural Heating

In view of the fact that NIST appears to have overestimated the intensity and duration of the fires in WTC 7, particularly on floors 12 and 13, it follows that the heating of the structural steel is also overestimated in the WTC 7 Draft Report. This is fatal to the overall validity of NIST's collapse initiation hypothesis because NIST's hypothesis is predicated on the thermal expansion of long span beams and girders on floors 12/13 and their eventual loss of connectivity with column 79, (See Chapter 8 of NCSTAR 1-9).

NIST's computer simulation of the thermal response of floors 12/13 is described in Chapter 10 of NCSTAR 1-9 and estimates temperatures as high as 675°C "*on much of the east side and the east portion of the south side of (floor 12)*". NIST also concludes that the temperatures of floor beams and girders on floors 12/13 were 600°C or higher for 1 - 2 hours.

The temperature vs. time profile of a structural steel member exposed to a fire and protected by a layer of insulation of thickness d_i is given by the formula:

$$\Delta T_s / \Delta t = [k_i / (d_i c_s \rho_s)] (A_p / V) (T_g - T_s)$$

where,

$\Delta T_s / \Delta t$ is the rate of change of the temperature of the steel

k_i is the thermal conductivity of the insulation material

c_s is the heat capacity of the steel

ρ_s is the density of the steel

A_p / V is the section factor of the steel member

$T_g - T_s$ is the temperature difference between the steel and the combustion gases

Values for the quantities k_i , d_i , c_s , ρ_s and A_p / V appropriate for calculations of the heating of structural members in WTC 7 are as follows:

$$k_i = 0.12 \text{ W/m} \cdot ^\circ\text{C} \text{ (Monokote MK-5)}$$

$$d_i = 0.015 \text{ m}$$

$$c_s = 660 \text{ J/kg} \cdot ^\circ\text{C}$$

$$\rho_s = 7800 \text{ kg/m}^3$$

$$A_p / V = 100 \text{ m}^{-1} \text{ (W33x130 girder)}$$

As discussed in Section 3.0 above, the duration and intensity of the fires on floors 12 and 13 of WTC 7 discussed by NIST in Chapter 10 of NCSTAR 1-9, appear to be inconsistent with the fuel loads used in NIST's simulations. However, based on data from A. Jowsey's thesis: *Fire Imposed Heat Fluxes for Structural Analysis*, (Edinburgh 2006), an upper layer gas temperature of 800 °C sustained for 40 minutes would appear to provide a more realistic description of the fires at the east side of floors 12 and 13 prior to the collapse of WTC 7. This leads to a predicted heating rate of 7.46 °C/min and a maximum temperature for the floor framing beams and girders near the critical column 79 of about 300 °C, or barely *half* the temperatures estimated for these structural members in the NIST WTC 7 Draft Report.

5.0 Collapse Initiation and Propagation

NIST's computer simulation of the collapse of WTC 7, as presented in Chapters 8 and 12 of NCSTAR 1-9, is remarkable for the low temperatures - as low as 100 °C - at which failures of connecting elements such as bolts and studs are predicted to have first occurred in WTC 7 after about 3:00 p.m. on 9/11. These failures were caused, so NIST asserts, by the thermal expansion of asymmetrical framing beams and girders on the east side of floors 12/13. Nevertheless, in NIST's model, complete separation of column 79 from lateral restraints to buckling is predicted to occur only at temperatures well above 300 °C. Thus NIST's collapse initiation hypothesis requires that structural steel temperatures on floors 12/13 significantly exceeded 300 °C - a condition I believe that could never have been realized with NIST's postulated 32 kg/m² or lower fuel loading.

However, assume for a moment that collapse initiation in WTC 7 did in fact occur as NIST states: by a thermally induced buckling failure of column 79 on floors 12/13. It would then be appropriate to ask: Is the collapse propagation mechanism proposed by NIST consistent with the *observed* collapse of WTC 7? If the answer to this question is indeed “Yes”, it would add credibility to NIST’s account of what happened to building 7 on 9/11 even if an inappropriate fuel loading was used. However, I would suggest that NIST’s account of the last ½ minute of the life of WTC 7 not only lacks crucial physical detail, but is also at odds with what was observed in the well-known collapse videos of WTC 7.

In NIST’s WTC 7 collapse simulation, the fires in the lower part of the building severely heat floors 12 and 13 near column 79 causing it to lose lateral support and buckle. Then, according to NIST, the entire section of column 79 *above* floor 14 began to descend and trigger a global “disproportionate” collapse of WTC 7. In NCSTAR 1-9, Chapter 12, page 57, it is claimed that the top of column 79 was moving downward within 0.2 seconds of its buckling between floor 5 and 14.

Let’s consider this alleged motion of column 79 in more detail. Figure 12-43 in Chapter 12 of NCSTAR 1-9 NIST shows column 79 buckling between floors 5 and 14 starting about 14.9 seconds into NIST’s collapse initiation simulation. The lateral displacement of column 79 is shown to be about 5.5 meters to the east of its normal, fully vertical position at floors 9/10 at 15.5 seconds into the simulation. A consideration of the geometry of a column buckling over a length of about 36 meters shows that a lateral displacement of 5.5 meters should lower the top of the column by about 0.8 meters. In the same collapse simulation timeframe, (14.9 – 15.5 seconds), NIST show in Figure 12-45 that the vertical displacement of column 79 at the roof level was in fact 0.83 meters in 0.6 seconds. This implies that column 79 was moving downwards with an acceleration of 4.6 m/s^2 or about ½ g which is a very dramatic motion for a column that was restrained by several framing beams and girders on all the undamaged and unheated floors above floor 14 just moments before collapse initiation. I would therefore ask NIST to explain how and why all lateral supports acting on column 79, from more than 30 upper floors, were simply ripped out or otherwise detached from their very secure connections in only 0.2 seconds?

To conclude this section I would like to briefly mention NIST’s simulation of the final global collapse of WTC 7. Of course we are all very familiar with what actually transpired during the final moments in the life of WTC 7 because of the numerous well-known videos of this dramatic event, as discussed in Chapter 5 of NCSTAR 1-9. These videos typically present an unobstructed view of at least the upper third of WTC 7 and permit the collapse to be followed for 4 - 5 seconds. The videos show the upper section of WTC descending very smoothly as an intact structure with the roofline remaining essentially horizontal until it passes behind buildings in the foreground. The only significant distortion of the boxed-shaped Building 7 that is noticeable after the façade begins its downward motion, is the formation of a slight kink on the eastern side of the north face.

Now consider NIST’s version of the final moments of WTC 7 as exemplified by the computer-generated simulacra of Figure 12-69 of NCSTAR 1-9. These images of the final collapse of WTC 7 from the north, west and south show very extensive buckling of the exterior columns especially near the mid-height of the building. It is simply astounding that, even though these computer generated images of a crumpled and severely distorted Building 7 look nothing like the video images of the real thing, NIST nevertheless concludes: “*the global collapse analyses matched the observed behavior reasonably well.*”

5.0 Conclusions

I believe there are many problems with the material presented in NIST's Draft WTC 7 Report; most of these problems stem from the fuel loading assumed by NIST but I would add that NIST's collapse hypothesis is not physically realistic and is not well supported by observations of the behavior of Building 7 during its collapse. I certainly believe that an alternative collapse initiation and propagation hypothesis is called for; an hypothesis that more accurately reflects the reality of what happened to WTC 7 on September 11th 2001.

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Subject: Comments on WTC 7 Report

To whom it may concern,

Please accept these further comments on the *WTC 7 Draft Report*:

Addendum:

**Additional Comments by F.R. Greening on NIST's Global Collapse
Analysis in Chapter 12 of NCSTAR 1-9**

In Chapter 12 of NCSTAR 1-9 NIST describes the main findings of its computer modeling of the collapse of WTC 7. Some of the key results of this modeling are also presented in Figures 12-48 to 12-69 to be found on pages 571 to 595 of Chapter 12.

In Section 5.0 of the Comments I submitted to NIST September 11th, 2008, I addressed some of my concerns with the material presented in Chapter 12 of the *Draft Report*. Here I wish to consider NIST's core collapse sequence in more detail especially the results illustrated by Figures 12-48 et seq. and Figures 12-66 et seq. in Chapter 12 of NCSTAR 1-9. These Figures show the vertical progression of core column failures on the east side of WTC 7 that, according to NIST, led to the collapse of the East Penthouse. NIST states that the WTC 7 core collapse started with the buckling of column 79 about 14 seconds into the computer simulation, and was followed by the descent of the East Penthouse below the roofline of WTC 7 at about 16.5 seconds into the simulation.

According to NIST, the global collapse of WTC 7 began 6.9 seconds after the East Penthouse collapse or about 23 seconds into the simulation. Now consider NIST's Figures 12-66, 12-67 and 12-69 and in particular the images showing the alleged state of the core 17.5, 19.5, 20.7, 21.8, 24.1, 26.8 and 28.8 seconds into the collapse simulation. These images represent NIST's view of what the core looked like at ~ 1 - 2 second intervals following the collapse of the East Penthouse. What is most significant about these images is that around the time of global collapse initiation NIST's simulation shows that the eastern half of the core had completely collapsed while the western half of the core remained standing and relatively undamaged. This is quite remarkable since videos of the collapse of WTC 7 show that up to *and well beyond* the moment that the roofline of WTC 7 exhibited its first downward movement, the exterior of the building revealed absolutely no signs of NIST's proposed partial collapse of the core even though the core was connected to the exterior walls of Building 7 by dozens of horizontal beams on every floor.

NIST's proposed collapse of the eastern half of the core would have completely removed the lateral restrains normally acting on the eastern exterior columns of WTC 7. Indeed, NIST assert that in the moments before global collapse initiation, "*the exterior façade on the east quarter of the building was just a hollow shell.*" This would have caused the eastern façade to buckle *well before* global collapse ensued. This buckling would have been visible as a bowing

of the northeast corner of the building. Needless to say, such pre-collapse buckling or bowing of WTC 7 was not observed. However, the problems with NIST's simulations only get worse *after* global collapse initiation. Thus Figure 12-68 of NCSTAR 1-9 shows that the western end of the WTC 7 core only started to collapse about 25 seconds into NIST's simulation, a full 2 seconds after NIST claims that global collapse was underway.

NIST states in NCSTAR 1-9 that 24.5 seconds into its simulation, the roof of WTC 7 was falling with a velocity of approximately 10 to 15 m/s, while Figure E-4 of NCSTAR 1-9A shows that the roofline of WTC 7 had descended about 3 stories at 24.6 seconds of the simulation, or 1.6 seconds into global collapse. These Figures are in complete contradiction to Figure 12-68 of NCSTAR 1-9 which shows a computer-generated image of WTC 7 taken 24.1 seconds into NIST's collapse simulation with the eastern end of the core completely collapsed, but the western end still standing, essentially undamaged, to within 0.5 meters of its full 186 meter height.

The images 26.8 and 28.8 seconds into NIST's simulation, or 3.8 and 5.8 seconds after the initiation of global collapse, deliver a final blow to the credibility of NIST's collapse simulation. Thus the 26.8 and 28.8 second images included in Figure 12-68 reveal a collapsing core with its eastern side a full eight stories, or about 32 meters, *below* its western side. This would indicate a roofline collapse that started at the eastern end of Building 7 and progressed over a period of about 4 seconds to the western end.

Now, if NIST's collapse simulations are supposed to accurately reflect what happened to Building 7 on 9/11, one is compelled to ask:

Why did WTC 7 undergo a strictly vertical collapse, with the roofline remaining essentially horizontal throughout the first 5 seconds of its downward motion, when NIST's simulations show the eastern side of the building starting to collapse 4 seconds before the western side?

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